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TWO RECENT VOLUMES OF DOUBLE-STAR MEASURES.*

A REVIEW, BY R. G. AITKEN.

We have several times called attention in these *Publications* to the fact that the progress of double-star astronomy in the last few years has been very satisfactory; the well-known binary stars have been followed more carefully than ever before, and their orbits revised and corrected by means of the new measures; old and neglected pairs have been looked up and measured; many new pairs have been discovered; and two of the most important catalogues of double stars—BURNHAM'S and OTTO STRUVE'S†—have been published in such form as to put all data relating to the stars they contain in convenient form for study.

But the field is large and the toilers in it even now none too many. Especially do we need all the measures we can get of the closer double stars—those that require large telescopes for their accurate measurement. Such contributions as the two volumes now under consideration are for this reason particularly welcome.

The first one contains the observations of 900 double stars made by Mr. ERIC DOOLITTLE with the new 18-inch telescope of the Flower Observatory, between the dates of January 1, 1897, and October 15, 1900. His observing list comprised "348 β stars, principally those which have not been measured since 1891, or of which, for other reasons, the character of the motion is uncertain; 471 miscellaneous stars, principally neglected pairs of the HERSCHELS and STRUVES, and including those (22) which are believed to be new; 55 stars noted as double in the catalogues of the *A. G.* Zones, 55°–70°, and previously measured by BURNHAM; and 33 stars of the 40 binary stars whose orbits have been computed by Dr. SEE."

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* *Publications of the University of Pennsylvania*, Astronomical Series, Vol. I, Part III. Measures of nine hundred Double and Multiple Stars, made with the Eighteen-inch Refractor of the Flower Astronomical Observatory, by ERIC DOOLITTLE.

Publications de Poulkovo, Série II, Vol. XII. Mikrometer-Messungen von Doppelsternen ausgeführt am 30-zölligen Refractor zu Pulkowa von HERMANN STRUVE.

† By W. J. HUSSEY, as Vol. V, *Publications* of the Lick Observatory.

The fact that Mr. Doolittle in selecting his list of stars had the benefit of advice from Mr. Burnham, to whose kindness all of the younger double-star observers owe so much, is in itself sufficient evidence that the work was worth doing; and a study of the measures shows that the work was well done. In general, each star was measured on at least three nights, the more rapid binaries in some cases on as many as fifteen or twenty nights, and great care was exercised to make the separate settings independent and to free the measures as far as possible from systematic errors. The results have been printed in very convenient and neat form, giving the observed data without any superfluous matter.

Professor Struve's volume contains the results of the observations made by him in the period 1885–1895 with the 30-inch telescope at Pulkowa. His working-list during the first year was made up of β stars, which were too difficult for observation with the 15-inch refractor. To those were added in the following year all the Struve and Otto Struve stars which, according to the measures by Struve, Otto Struve, and Dembowski, had given evidence of motion, and also a few other interesting stars. This brought the total number of stars to about 900,—470 Σ stars, 190 OΣ stars, 200 β stars, and 30 miscellaneous pairs. As the telescope was also used for extensive series of satellite measures and for spectroscopic work, the work on this double-star programme was so much interrupted that when Professor Struve left Pulkowa in 1895 measures had been made of but 750 of these pairs. Special attention had been given, however, to the closer pairs and those in rapid motion,—as for example, ζ *Cancri,* ε *Hydræ,* ζ *Herculis,* and δ *Equulei,*—and in all about 3,100 separate measures were made.

Professor Struve devotes the greater part of his introduction to this volume to the discussion of the systematic errors of his observations.

In measuring the angle of pairs separated by 5″ or more, he followed the method of bisecting both stars with a single wire; but the position-angles of the closer pairs were measured by the "usual method,"—that is, by placing the stars midway between two wires slightly separated.

Four settings were generally made, the eyes being kept parallel or perpendicular to the line joining the stars. Double distances were measured, four settings being made ordinarily.

To determine the systematic errors directly, many of the stars were measured repeatedly at different hour-angles and with eyes parallel and perpendicular to the line joining the stars, and measures with a very high power were also compared with those made with the lower-power eye-piece, which was more generally used.

Professor STRUVE concludes that his observations in angle are affected by small systematic errors, which, in the case of angles measured by the "usual method," vary with the hour-angle and the position of the eyes. The position of the fainter star, to the right or left, above or below the primary, also exercises an appreciable effect. The measures made by the method of bisection do not seem to be affected by the hour-angle nor by the position of the eyes. But while the systematic errors seem to be real, they are in all cases small, the final result being that his angle-measures require an average correction of + 0°.42.

This direct investigation is confirmed by comparisons with the measures of W. STRUVE and DEMBOWSKI, which lead to an average correction of + 0°.38.

The comparison of his distance-measures with those of these two observers indicates that his own are practically free from systematic errors.

Professor STRUVE also gives an interesting comparison of his measures of twenty-seven binary stars with the computed positions derived from Dr. SEE's orbits. The table shows the observed positions, the residuals HΣ — computed, and also the residuals (O — C) given by Dr. SEE for the corresponding dates. Dr. STRUVE, for reasons that are readily apparent, does not use this material to determine his systematic errors definitely. But it occurred to me in examining the table that corroborative testimony could be drawn from it by comparing the two columns of residuals. This would give residuals HΣ — O where O indicates the mean of the observed positions as combined by Dr. SEE for the basis of his computations. Assuming these means to be free from systematic error (an assumption not wholly warranted) the residuals will give H. STRUVE's systematic errors. I have made this comparison, and find that the average residual in angle (omitting two abnormal residuals of + 13°.6 and + 16°.4, respectively) is — 0°.32, and in distance + 0″.028. The systematic corrections are therefore + 0°.32 and — 0″.028, results which, so far as their evidence goes, confirm the observer's own conclusions.

Professor Struve has also investigated the probable error of his measures dividing the stars into classes according to the measured distances. He finds that the maximum probable error is less than ± 0″.09 in either coördinate,—a result that is very satisfactory.

It is evident from these investigations that the measures possess a high degree of accuracy.

It may perhaps be noted as a matter of some practical interest that both Doolittle and Struve differ from the present observers at the Lick Observatory (and, I believe, from Burnham and Barnard also) in their method of measuring the angles of "stars not very far apart." They place the stars midway between two wires separated by a few seconds of arc; we use the method of bisection with a single wire.[*]

The former method is the one used by practically all the earlier double-star observers, and by many excellent observers at the present time as well; but I am satisfied that better results, —that is, results more likely to be free from systematic error,— are attainable by the latter method, especially if the use of the tangent-screw is dispensed with and the settings are made with the pinion, the wire being moved quickly to either side of the true position a number of times before final adjustment.

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[*] See Professor Hussey's statement, which represents my observing practice as well, in *Publications* Lick Observatory, Vol. V, p. 13.